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Growth and Yield of Rice as Affected by Soil Water Deficits

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ABSTRACT

The response of growth and yield of rice (*Oryza sativa* L.), cultivar Tainung 67, to soil water deficits imposed at different growth stages was studied during the second crop of 1993 and the first crop of 1994 at the experimental farm of Taiwan Agricultural Research Institute. Results showed that leaf area was decreased in the later growth phase in the second crop as water deficit imposed on the vegetative stage. When imposed on the panicle formation stage, leaf number and leaf area were decreased. No significant difference was found in the growth characters among treatments in the first crop. The grain yield reduced to 86 and 83% of its maximum when water potential decreased to -0.75 and -0.50 MPa in the vegetative and the panicle formation stages, respectively, in the second crop of 1993. Yield was further reduced to only 31% when water potential declined to -1.00 MPa in the panicle formation stage. It was 85 and 74% when water deficit reached to -0.75 and -0.50 MPa in the first crop of 1994 in the corresponding stages. The spikelets per panicle was significantly decreased at -0.50 MPa or lower when water deficit occurred in either stage in both crops. In 1993, percent filled spikelets and 1000-grain weight were also decreased when water potential dropped to -1.00 MPa in the panicle formation stage.

Key words: Growth, Yield, Rice, Water deficit, Drought, Climate.

土壤缺水對水稻生長與產量之影響

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摘　要：本文之研究目的，旨在探討不同生育時期土壤缺水對不同期作臺農 67 號水稻 (*Oryza sativa* L. cv. Tainung 67) 生長與產量的影響。田間試驗自 1993 年二期作至 1994 年一期作止，在臺灣省農業試驗所農場進行。試驗結果顯示，二期作之營養生長期（分蘗盛期）土壤缺水將減少生育後期稻叢葉面積，穗形成期（自幼穗分化至抽穗）之缺水則使葉片數及葉面積同時降低。在本試驗之缺水程度，一期作的缺水處理均未造成生長性狀顯著差異。在 1993 年二期作，當土壤水分潛勢分別在營養生長期及穗形成期下降至-0.75 及-0.5 MPa 時，穀粒產量分別降至對照組的 86 及 83%。穗形成期之土壤水分潛勢續降至-1.00 MPa 時，產量將減為 31%。若發生在 1994 年一期作，營養生長期 (-0.75 MPa) 及穗形成期 (-0.50 MPa) 的缺水處理則分別使產量減為 85 及 74%。產量性狀中，當土壤水分潛勢下降至-0.50 MPa 或以下時，無論生育期及期作均促使每穗籽粒數明顯降低。1993 年二期作的穗形成期缺水至-1.00 MPa 時，籽粒充實率（稔實率）及千粒重亦顯著減少。

關鍵詞：生長，產量，水稻，缺水，乾旱，氣候。

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INTRODUCTION

Rice is usually grown in submerged paddy supplied with ample of water and hence draws little regard on drought problems relative to dryland crops. In recent years, however, studies on the morphological and physiological adaptation mechanisms in rice plants upon soil water deficits have received much attention (Chu and Li, 1979; Culter *et al.*, 1980; O'Toole and Chang, 1979; Sung *et al.*, 1983; Tomar and O'-Toole, 1982; Yang *et al.*, 1983). In a field experiment, Yang (1994) showed a positive relationship of rice yield with solar radiation and heat sum and demonstrated the effects of soil water deficits on yield production. Others have reported yield loss by prolonged water stress in many crops (Nageswara Rao *et al.*, 1985; Pahalwan and Tripathi, 1984; Wardlaw, 1971; Yang *et al.*, 1993).

McCree and Fernandez (1989) and Jones and Zur (1984) introduced simulation model to study physiological responses of whole plants to water stress. Nevertheless, the inputs of the model must be based on data from experiments and such models generally overlook the dynamic nature of plants in the real world. Long-term field study on changes of growth characters and yield potential to water stress, therefore, provides valuable information for water management and cultivation practices.

The study was undertaken to investigate long-term growth performance of rice to soil water deficits. The differences of yield and its components as affected by different levels of water stress were analyzed. Emphasis was placed on the occurrence of water deficits in either the vegetative or the panicle formation stage.

MATERIALS AND METHODS

The experiment was conducted during the second crop of 1993 and the first crop of 1994 at the Taiwan Agricultural Research Institute, Wufeng, Taichung Hsien, Taiwan. Climatic conditions during the cropping seasons are given in Table 1. Measurements and calculations of weather parameters daily mean temperature, irradiacne, precipitation, and sunshine hour were described in details elsewhere (Yang, 1994). Water deficit treatments were imposed by withholding irrigation in the vegetative (active tillering) or the panicle formation (from panicle initiation to heading) stage to the desired levels. The stressed plots were then re-irrigated as that of control until harvest. The individual stress periods were listed in Table 2.

The experimental design was a s-

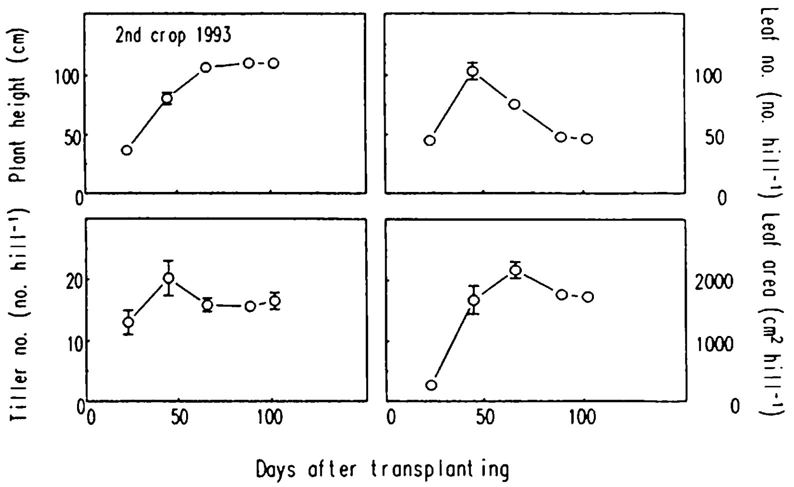
Table 1. Climatic conditions during the growing seasons of rice cultivar Tainung 67 at the experimental farm of TARI, Taichung Hsien, Taiwan (ROC).

Crop season	Heat sum (℃)	Precipitation (mm)	Irradiance (MJ m^{-2})	Sunshine hour (h)
2nd crop 1993	2641.3	177.5	1420.89	600.9
Daily average	25.9	1.7	13.93	5.9
1st crop 1994	2592.5	446.0	1369.23	398.2
Daily average	22.5	3.9	11.91	3.5

correlation between rice yield and solar radiation and heat sum and such relationship exists even under water stress.

The growth patterns of the second and the first crops of control plants were graphed in Fig. 1a and 1b. Except plant height, a general trend was shown in tiller number, leaf number and leaf area that these growth characters was decreased after reached the climax. As water deficit imposed on the vegetative stage, leaf area was decreased in the later growth phase in the second crop (Fig. 2a). When imposed on the panicle formation stage, leaf number and leaf area were also decreased. No significant difference was found in the growth characters among treatments in the first crop (Fig. 2b). Changes of dry weights of leaf, sheath and shoot (leaf plus sheath) for both crops of control plants were plotted in Fig. 3. It was shown that leaf dry weight was decreased more in the second crop than in the first crop (Fig. 2a and 2b).

The results can be explained by the climatic data, since the higher values of temperature and irradiance stimulate more transpiration from the plant and evaporation from the soil that en-



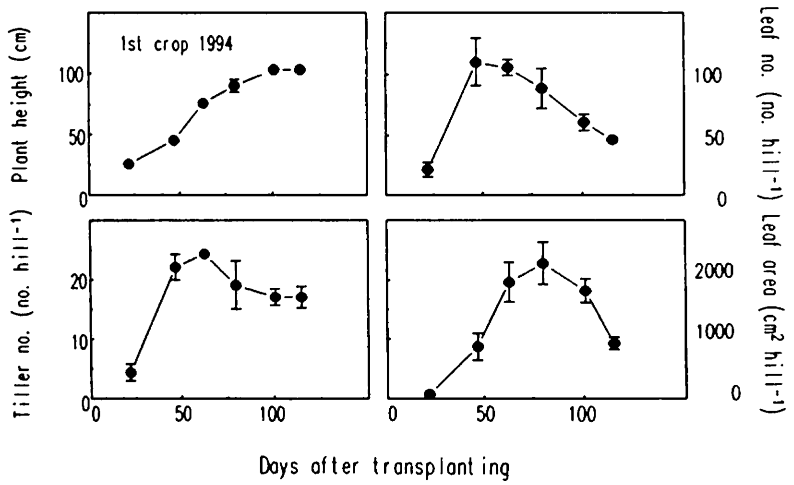
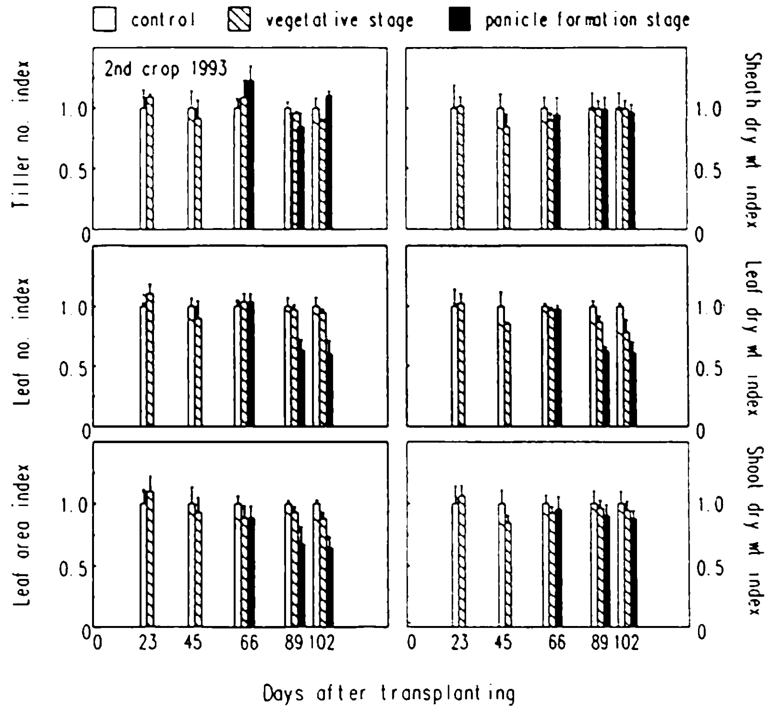


Fig. 1a. Changes of growth characters of rice cultivar Tainung 67 during the growing season of the 2nd crop of 1993. The standard deviation is included.

Fig. 1b. Changes of growth characters of rice cultivar Tainung 67 during the growing season of the 1st crop of 1994.



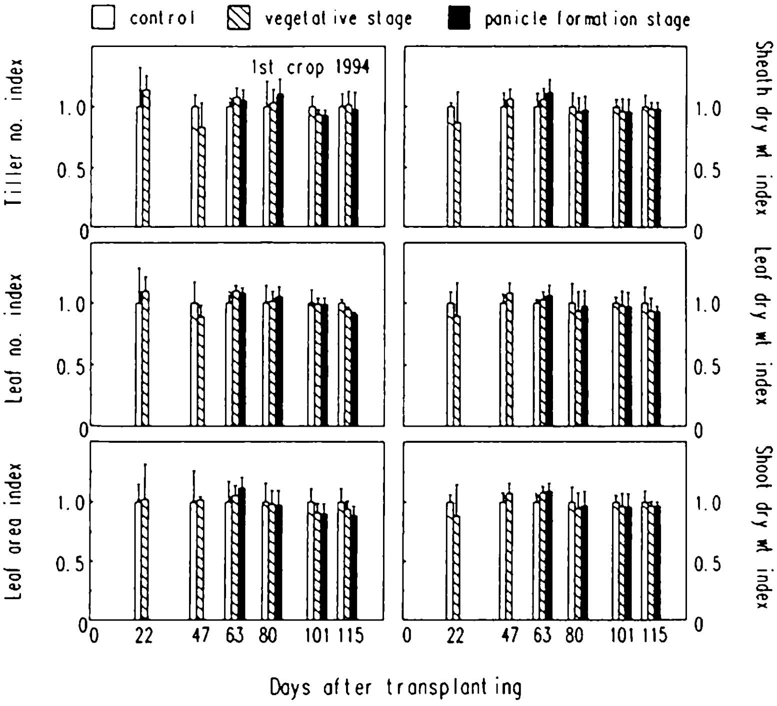


Fig. 2a. Effect of soil water deficits at different growth stages on the changes of growth characters of rice cultivar Tainung 67 during the growing season of the 2nd crop of 1993. The index value was calculated by dividing growth character from treated rice with growth character from the control.

Fig. 2b. Effect of soil water deficits at different growth stages on the changes of growth characters of rice cultivar Tainung 67 during the growing season of the 1st crop of 1994. The index value was calculated by dividing growth character from treated rice with growth character from the control.

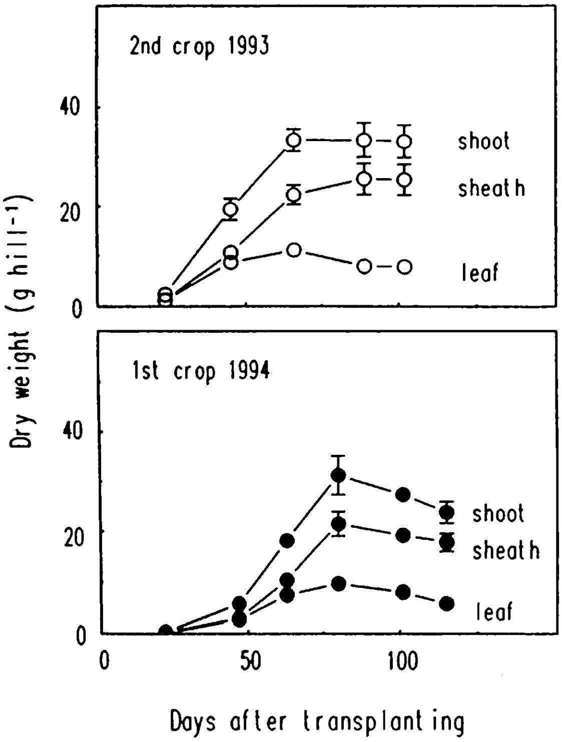


Fig. 3. Changes of dry weights of sheath, leaf and shoot (sheath plus leaf) of control plants of rice cultivar Tainung 67 during the growing seasons of the 2nd crop of 1993 and the 1st crop of 1994. The standard deviation is included.

danger the growth of rice in the field (Singh and Sasahara, 1981; Sung *et al.*, 1983; Tomar and O'Toole, 1982).

Under conditions of no rain or irrigation but high evaporative demand of the atmosphere, water deficits develop in plants as water loss from the leaves surpasses water uptake by roots and reaches a level which decreases the growth processes (Hsiao, 1973). With higher temperature and irradiance but less available water, stress injury will be accelerated.

The grain yield of rice reduced to 86 and 83% of its maximum when soil water potential dropped to -0.75 and -0.50 MPa in the vegetative and the panicle formation stages, respectively, in the second crop of 1993 (Table 3). The yield was further reduced to only 31% when water potential declined to -1.00 MPa in the panicle formation stage. It was 85 and 74% when water deficit reached to -0.75 and -0.50 MPa in the first crop of 1994 in the corresponding stages. Apparently the reduction of rice yield was more severe when water deficit occurring in the panicle formation stage. The results were compatible with that reported by Yang (1994), where yield reduced to 77 and 79% for the first crop of 1991 and the second crop of 1992 as soil water potential decreased to -0.75 MPa in the vegetative stage. It was 76 and 79% when stress occurred in the panicle formation stage at -0.50 MPa. Biswas and Choudhuri (1984) concluded that boot stage and milk-ripe stage are stages of rice that most sensitive to water stress. In peanut, Nageswara Rao *et al.* (1985) showed that water deficits can affect peanut yields differentially depending on time of occurrence and intensity.

The spikelets per panicle was significantly decreased at -0.50 MPa or lower when water deficit occurred in either stage in both crops (Table 4). In 1993, percent filled spikelets and 1000-grain weight were also decreased when soil water potential dropped to -1.00 MPa in the panicle formation stage. Results imply that spikelets per panicle was affected in moderate water deficit while percent filled spikelets and 1000-grain weight were influenced by severe stress. Similar results were reported by Biswas and Choudhuri (1984) that yield components of rice were affected by

Table 3. Effects of soil water deficits on grain yield of rice cultivar Tainung 67 at the 2nd crop of 1993 and the 1st crop 1994.

Crop season	Treatment	Grain yield (kg ha^{-1})	Index
2nd crop 1993	Control	5620	100
	V (-0.75 MPa)	4830	86
	P (-0.50 MPa)	4690	83
	P (-1.00 MPa)	1760	31
	LSD(0.05)	450	
1st crop 1994	Control	6470	100
	V (-0.75 MPa)	5480	85
	P (-0.50 MPa)	4760	74
	LSD(0.05)	1070	

Table 4. Effects of soil water deficits on yield components of rice cultivar Tainung 67 at the 2nd crop of 1993 and the 1st crop 1994.

Crop season	Treatment	Panicles ($hill^{-1}$)	Spikelets ($panicle^{-1}$)	% filled spikelets	1000-grain weight(g)
2nd crop 1993	Control	16.0	70.5	75.2	23.28
	V (-0.75 MPa)	16.1	58.2	69.6	21.49
	P (-0.50 MPa)	16.5	57.0	61.3	21.24
	P (-1.00 MPa)	13.8	18.7	33.4	18.67
	LSD(0.05)	1.4	9.9	17.2	3.74
1st crop 1994	Control	16.9	73.1	87.6	24.42
	V (-0.75 MPa)	16.5	64.4	87.7	23.33
	P (-0.50 MPa)	16.1	58.0	87.0	22.23
	LSD(0.05)	3.3	5.2	3.0	2.31

the severity of water stress.

It is no doubt that soil water d-eficits and drought affect the growth and yield of rice. The present experiment further indicated that the reduction of growth and yield depends on growth status and crop season of rice and the magnitude of water shortage. Thus, it suggests that proper irrigation management is necessary for better water use efficiency and profit gain in water resources limited area such as Taiwan.

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